Title - Leaky deltas: sources or sinks in the global carbon cycle?

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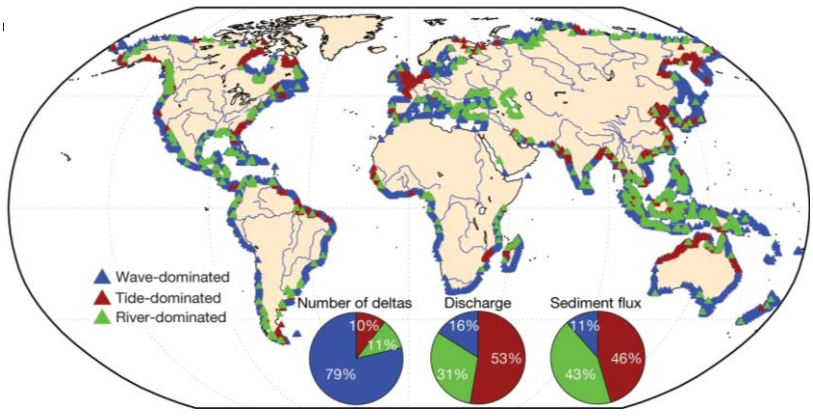
PURPOSE/SUMMARY: Despite their relatively small areal extent, river deltas have global relevance as major centers of marine primary production, biogeochemical transformations, and human activity that all impact the global carbon cycle. But significant and critical knowledge gaps remain on relevant processes, their impacts on marine biogeochemistry, and the direction of future change. Here we propose to assemble ~70 scientists and students across all career stages for a **3-day scoping workshop in spring 2025** to address these knowledge gaps. We will bring together a diverse group who are committed to exploring the physical, temporal, and biogeochemical processes that modulate fluxes of carbon to and from global deltas. We plan to bolster community engagement and participation, with a particular emphasis on inclusion of minoritized populations, international partners, and state and federal U.S agencies through targeted activities, before, during, and after the workshop. This scoping workshop will utilize momentum from an OCB 2023 Summer Workshop plenary session focused on deltaic systems to build a network of modelers, experimentalists, and field scientists working on deltas in this era of unprecedented climate change and other anthropogenic stresses.

INTRODUCTION AND RATIONALE

Deltas and the adjacent coastal ocean are critical interfaces between terrestrial and oceanic environments. Approximately 50% of the fresh water and 40% of all global particulate matter enters the ocean through deltas. They are major centers for particulate and dissolved organic carbon (OC) net transfer from land to ocean, generally estimated at 0.21 and 0.5 Pg C per year respectively (Bianchi and Allison 2009). Their global relevance for OC burial is evident from the magnitude of material fluxes to these regions, with about 80% of the total organic carbon preservation in marine sediments occurring in coastal regions near the river mouths. Delta plains and their mangrove forests and tidal marshes, which comprise only ~0.5% of the seabed, are an important part of the blue carbon ecosystems that store carbon and provide co-benefits such as coastal protection and fisheries enhancement (Macreadie et al., 2021). Globally, these coastal wetland ecosystems, most of which are on river deltas, store at least 45 Tg C yr^{-1} (Chmura et al., 2003), and represent the second largest global sink for atmospheric CO_2 (Regnier et al., 2022). Considerable uncertainty remains in our ability to adequately quantify carbon exchange, and consequently associated nutrients and trace elements, from land to the coastal ocean (or vice versa) through these deltaic systems and understand the processes influencing the fate of terrigenous carbon in coastal sediments.

Figure 1: Geographic global distribution of pristine delta morphologies (from Nienhuis et al., 2020)

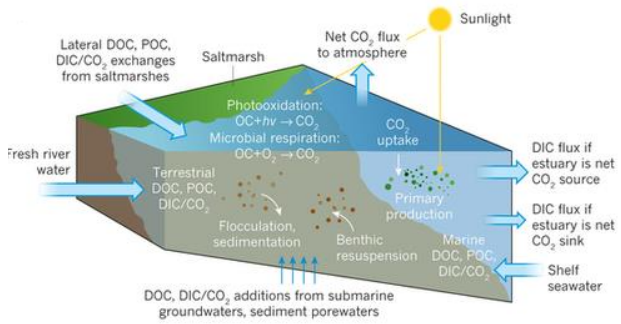


Current carbon budgets across the delta system, which spans delta plains, tidal wetlands, estuaries, and shelf waters, are limited although studies show that coastal carbon budgets should explicitly include them and the linkages between them. The morphologies and ecosystems of deltas, and their functioning, are increasingly perturbed by climate change and other anthropogenic stresses. Deltas are densely populated, and the natural processes that transport and transform carbon have been substantially perturbed by human activities. The response to these perturbations is varied and diverse, with deltas

worldwide experiencing a net land gain of 54 km^2 yr^{-1} in last 30 years but at the same time over 1000 deltas worldwide have lost 12 km^2 yr^{-1} (Nienhuis et al., 2020). These alterations are likely to accelerate in the coming century, and the implications for deltaic carbon transport and transformation and its effects on the coastal carbon budget remain unknown. Recent evidence suggests that coastal oceans have become net sink for atmospheric CO2 during post-industrial times and continued human pressures in coastal zones and alterations to deltas will probably have an important impact on the future evolution of the coastal ocean's carbon budget.

Despite the importance of deltas and blue carbon ecosystems to the global carbon cycle and coastal communities, land-to-ocean parameterizations in Earth System models are highly simplified and do not mechanistically include many of the processes involved in cycling carbon in these areas. Including salt marshes and mangroves in biogeochemical models remains a challenge that needs to be addressed to close gaps in the global carbon budget. Collecting spatially representative measurements of carbon composition and associated biogeochemical transformations across the river-delta-shelf transition is critical for constraining the loss of carbon during transport and deposition. Reconstructions and forecasts of deltaic land-use and ecological change drawn from field observations are also needed as model calibration and input. Emergent tools such as remote sensing and optically stimulated luminescence dating have in recent decades provided new avenues for research (e.g., Chamberlain et al., 2020). Utilizing such tools in combination with long-established approaches will facilitate identifying the associated processes and feedbacks of carbon cycling at micro- to macro- levels and thereby support development of more mechanistically precise models to understand the role of deltas in the global carbon cycle. Developing this integrated, holistic, interdisciplinary knowledge requires a diverse team and concerted effort.

Figure 2: The channels, wetlands, and coastal ocean of deltas comprise complex pathways of carbon transfer and transformation (modified from Bauer et al., 2013)



WORKSHOP OBJECTIVE

Our proposed scoping workshop will continue to build on the inspiration and momentum gained from a OCB 2023 plenary session ("Role of deltaic sediments in regulating biogeochemical cycles") and aim to synthesize our current understanding and knowledge gaps of the **role of deltas in the global carbon budget in terms of sources, sinks and transformation of carbon along the delta-ocean continuum.** We will propose directions for future research and integration among different scientific communities working on this issue**.** The workshop will specifically focus on (i) biogeochemical transformation of organic matter and nutrient inputs from rivers through these deltaic systems into the adjacent coastal ocean; (ii) the role of deltaic ecosystems in the transformation of marine and terrestrial organic matter; (iii) the response of deltas and their ecosystems to perturbations such as sea-level rise; (iv) emergent tools that can be applied to characterizing deltaic systems; and (v) advances in biogeochemical and sedimentary modeling approaches and inputs, including reconstructions and field data, across deltas and the coastal ocean.

CONTRIBUTION TO OCB

The proposed scoping workshop will address and advance several OCB mission-specific topics. The themes of the workshop will target (1) human and climate-driven changes in ocean biogeochemistry and related marine ecosystem impacts; (2) carbon cycling, storage, uptake, and modulation at a critical land-ocean interface along the aquatic continuum; (3) sedimentary fluxes and benthic-pelagic coupling as they relate to C, nutrients, and other elemental cycles e.g., O_2, Fe, Mn; (4) marine organism response to environmental changes associated with delta loss, subsidence, salinization, and other anthropogenic disturbances; and (5) promotion of minoritized shareholders in inclusive and equitable scientific discussions of unprecedented impacts of human-driven changes to deltaic systems.

PRE-WORKSHOP ACTIVITIES

We propose a series of 6-7 pre-workshop activities to promote national and international community engagement in the form of (1) remote townhalls, (2) sessions at Goldschmidt (2024) and AGU (2024), (3) gatherings with NASA DeltaX, CMS, and CSDMS communities at their annual meetings, and (4) electronic surveys sent to townhall participants and session attendees (with their permission) to determine several community-consensus-driven topics that will be highlighted in the 3-day scoping workshop. The remote town halls and presentations will be advertised broadly to increase attendance and involve participation from a diverse group of scientists and shareholders. We will invite several groups such as CSDMS (Community Surface Dynamics Modeling System), NASA Delta X, NASA CMS (Carbon Monitoring System), the international Delta Alliance organization (www.delta-alliance.org), and the CIRES Earthlab (earthlab.colorado.edu). Organizers Marisa Repasch and Shaily Rahman will submit a proposal for a session on the role of deltas in the global carbon cycle at Goldschmidt 2024.

There are several key objectives of the pre-workshop activities: (1) Recruit and build a community from an interdisciplinary group including geomorphologists, modelers, biogeochemists, paleoclimatologists, scientists with expertise in remote sensing technologies, scientists who integrate data across spatial-temporal scales, and of varying career stage, to study delta dynamics and associated impacts to marine C fluxes. (2) Compile and prioritize unresolved scientific questions or problems in the coupling between delta dynamics and marine C fluxes. (3) Engage with and query community to begin achieving community consensus. We will promote DEI in the pre-workshop activities by inviting speakers from different continents to promote global representation and include in our discussions the different location-based needs from different communities across the globe. We will work with non-native English and early-career speakers before the actual online events via practice presentations to make them more comfortable and as a form of professional development.

WORKSHOP ACTIVITIES

Workshop Topics: We propose to hold a 3-day workshop at Louisiana State University (LSU) in Baton Rouge, USA, in February or March 2025. In those 3 days, we will have talks in the morning, breakout groups in the afternoon, and discussions of the breakout group findings over dinner as well as a late-afternoon excursion. Talks will focus on the following topics outlined below, which we (1) compiled and identified during the OCB 2023 Summer Workshop from our conversation between plenary speakers and OCB participants, and (2) during subsequent discussions between plenary speakers during the development of this proposal:

- **Ocean biogeochemistry:** Influence of delta systems on adjacent coastal ocean in terms of carbon cycle (DIC/ALK/pCO_2) both in water column and sediment, carbon burial and lateral transport of carbon.
- **Ecosystems:** Role of salt marshes, mangroves, and sea grass on carbon retention and burial in delta plain and net export to adjacent ocean; reconstructions and forecasts of the distribution of these coastal ecosystems.
- **Novel methods and integration:** Employing new technologies, e.g., chronology, remote sensing, to reconstruct and monitor delta change; integrating field and model data to study processes and change across timescales (past, present, and future).
- **Connectivity:** Variability in hydrological connectivity across delta plain and delta shelf and its impact on carbon consumption, transport and retention.
- **Perturbations –** Impact of climate and human driven changes including extreme events on delta carbon cycling.
- **Biogeochemical modeling:** including mechanistic understanding of carbon cycling in the land-to-ocean continuum in global models, parameterizations of blue carbon ecosystems in high-resolution ocean models, quantifying organic and inorganic carbon transfers from deltas to the ocean.
- **Climate solutions/mitigation**: Blue carbon storage, carbon loss/gain associated with land loss/gain, carbon benefit of created marshes, alkalinity enhancement through river deltas – mCDR.
- **Community consensus Topic #1 and Topic # 2**

Excursion: As an icebreaker and team building exercise, an excursion is planned in the later afternoon of the first day to the LSU Center for River Studies (https://coastal.la.gov/center-for-river-studies/), located directly along the Mississippi River near downtown Baton Rouge. Here, workshop attendees will learn about the unique hydrological and ecological setting of the Mississippi Delta and its source river through a ~1-hr guided tour and visit to the Lower Mississippi River Physical Model, a large scale (90 ft. x 120 ft) movable-bed physical model.

Workshop format: The workshop will occur over 3 days, covering ~2 topic plenary sessions per day and allowing time for discussion and work on ideation activities and deliverables in breakout groups. The 2-3 hour-long plenary sessions will consist of a mix of longer 30-minute talks and short 3-4 minute long lightning talks. The remainder of the day will be dedicated to break-out group activities. The excursion will be held on the first day to promote interaction and build a sense of community early in the workshop.

Table 1: Tentative Meeting Agenda

Day	Morning	Afternoon	Evening
Day 0	Arrival, check-in, poster set-up, and evening mixer. Welcome attendees and provide brief workshop introduction with goals, expectations, code of conduct.		
Day 1	-Open the workshop -Plenaries -Lightning Talks	-Lunch -Breakout groups (Discussion and identifying unresolved scientific questions) -Reporting back and online mentimeter/feedback polls -Excursion to the LSU Center for River Studies, to build comradery and gain inspiration	-Dinner and networking reception -Evening SOC meeting: Debrief on Day 1 activities and develop Day 2 activities based on Day 1 discussions & feedback
Day 2	-Plenaries -Lightning Talks -Poster session	Lunch -TWO Breakout/working group sessions to consider knowledge gaps identified on Day 1: (1) assigned by SOC for a mix of disciplines; and (2) by career stage -Reporting back (without participant identifiers to promote early-career and minoritized voices) and online feedback poll (what did discussion miss)	-Dinner groups at and dinner on own -Evening SOC meeting: Debrief on Day 2 activities, develop focused discussion & working breakout group implementation for Day 3; consider any course corrections based on feedback polls
Day 3	-One plenary -Breakout groups to work on identified deliverables	-Lunch -Breakout groups to work on deliverables -Breakout groups to brainstorm ways to increase community participation -Evaluate whether community consensus was achieved during the workshop -Adjourn early afternoon (4PM)	-Late afternoon/evening SOC Meeting: Debrief on Day 3 activities; assess progress on deliverables; planning of workshop report write-up -Dinner: SOC, wrap-up discussion

DELIVERABLES: In our breakout groups, we will work to synthesize the following deliverables

1. A community consensus paper on the unresolved scientific questions surrounding deltas and marine carbon (styled after Blöschl et al., (2019)
2. An infographic on the global delta carbon budget
3. AGU Eos-piece on the workshop

POST-WORKSHOP ACTIVITIES

We will organize follow-up activities to finalize the deliverables itemized above. For this, a shared

folder will be created. Workshop organizers will hold biweekly online check-ins to discuss progress on live, editable shared documents. We aim to finalize the consensus paper, infographic, and AGU Eos piece within three months following the workshop. We will present the working drafts and finalized outcomes at EGU (2025), the NASA Annual CMS meeting, Goldschmidt 2025, and at AGU (2025).

PLANNED OUTCOMES AND BENEFITS TO BROADER COMMUNITY

The workshop and associated activities yield both tangible and less readily quantified benefits to the community. At a primary level, the workshop will make strides toward developing knowledge and defining future research needs regarding the role of deltas in the global carbon cycle – an understudied yet critical aspect of ocean biochemistry. This information will be communicated to the broader community through the tangible products of a consensus paper, global delta carbon budget infographic, and AGU Eos piece. At a less tangible level, the workshop extends a nascent effort within our community to form an interdisciplinary and diverse team to address this challenging facet of ocean biochemistry by bringing together ~70 scientists and students within the field. Broader impacts include network building across academic generations, expertise, and internationality. The proposed activities will facilitate professionalization of early career and minoritized members of the community through e.g., coaching on practice presentations. The inclusion of international team members will foster understanding of the different and spatially variable aspects of deltas and carbon by drawing from different regional experiences, and inclusion of state and federal employees will support linking science to policy. We plan to utilize the 2+2 BS program being implemented between LSU College of Coast and Environment and Baton Rouge Community College to broaden participation of students from underrepresented communities and facilitate participation of undergraduate students. Broadly, we hope the workshop will serve as a springboard to initiate greater knowledge, research, and action on an understudied and critical topic while advancing DEI initiatives within our community.

Table 2: Requested Workshop Budget and Justification

Item	**$ per person**	**People**	**$ total**
Airfare/Travel (Domestic)	$500	20 (6 invited speakers, 4 organizers, 10 early career/minoritized participant)	10,000
Travel (International)	$1000	7 (2 invited speakers; 2 organizers, 3 early career/minoritized scientists)	7,000
Lodging	~$150/night for 4 nights/participant	50 out-of-town	30,000
Shuttle	$25/day for 3 days	70	5,250
Catering	$80/participant for 3 days	70	16,800
Conference Room& A/V Equipment Rental			5,000
Total			**74,050**

Envisioned participants, travel, and lodging: We envision 70 attendees including 50 out-of-town (with associated travel and lodging costs) and 20 within commuting distance of LSU (for whom travel and lodging are not budgeted). We budget domestic and international airfare for 20 and 7 participants, respectively. The workshop application will contain a short section where participants can indicate and provide a brief supporting statement if they would like to be considered for travel funding. The remaining 23 out-of-town participants will be responsible for their own travel costs. Lodging will be provided for all 50 out-of-town participants and will be arranged at one or two of the many hotel options within Baton Rouge.
At-workshop costs: Catering will provide three meals per day, buffet style, to all conference attendees, and a shuttle will be arranged to transport participants between hotels and facilities. We budget for the rental of one conference room that can hold all workshop participants, whereas remaining rooms for break-out group activities can be booked free-of-charge at LSU. The excursion will utilize the shuttles for transportation and the free guided tour offered by the LSU Center for River Studies, thereby not adding to the costs of the workshop.

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